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# Prospect Drilling

George Allen Mealey

Mining 68
Spring Semester , 1956
Mining Methods

Report
Submitted to
Professor K. S. Stout

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Professor K.S. Stout
Department of Mining
Montana School of Mines
Butte, Montana

Dear Professor Stout:

As directed at the beginning of this semester, I submit the following report concerning Prospect Drilling .

Most of the information that I have secured for this report came from professional magazines in the Montana School of Mines Library. Textbooks used here at the Montana School of Mines, together with infromation secured from students and professors ha s also been a great aid.

This report covers four types of prospect drilling: churn drilling, diamond drilling, percussion drilling and calyx drilling. No other types of prospect drilling are discussed except these four types, because any other methods are not extensively used.

Sincerely,

George Allen Mealey

George Allen Mealey

# PROSPECT DRILLING

## I. INTRODUCTION

Drill holes are employed extensively to investigate blocks of ground that by any other means would be accessible only at much greater expense, if at all. Drill hole investigations can be of three types:[1]

1. To secure geological information.
2. To determine the presence or absence of veins or other guides to ore.
3. To take samples of the ore and to provide all information that is required for an estimate of tonnage and grade.

When deposits are irregularly and erratically mineralized, drilling results are not to be depended upon as a basis in making accurate estimates upon grade of ore. In irregular deposits, drilling has value principally for determining geological structure, formations passed through, nature of mineralization, and other information useful as a guide to exploration.[2]

In some drilling campaigns, drill hole investigations are performed merely to confirm the presence of ore before further investigation takes place by additional

[1] H.E. McKinstry, Mining Geology, (New York, 1953) p. 70.

[2] C.F. Jackson and J.B. Knaebel, Sampling and Estimation of Ore Deposits (Washington, 1932), p. 5.

drilling or by some other means. If a "property" shows possibilities of containing ore or yielding geological information a planned drilling campaign may be set up or some other method of exploration may be started.

If an ore deposit is of a type in which mineralization is regular and uniform, drilling methods may give samples of ore to provide all the information that is required for an estimate of tonnage and grade. If drill samples are properly taken and interpreted, they can be relied upon for making estimates of grade and value that will check closely with actual results from later mining and drilling operations.[3]

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[3]Jackson and Knaebel, op. cit., p. 5.

## II. TYPES OF DRILLS

Diamond drills, churn drills, hammer drills and shot drills are the types most widely used for sampling and exploration in connection with metal mining.[4] It is not the purpose of this paper to discuss details of drill construction and operation, nor to explain the use of every type of prospect drill in use. The purpose of this paper will be limited to the explanation of prospect drilling in consolidated material, using todays most popular methods and excluding such drills as the wash-boring rigs, hand augers and the Empire drill which are used chiefly in unconsolidated materials.

### A. Churn Drill

In churn drilling a verticle hole is dug using a bit hung on a cable to which a rectilinear motion is imparted by one of the various types of power units. The bit is raised a few feet and then dropped to produce a churning motion of the bit which abrades the ground, and a hole is dug. The small pieces of rock thus produced form a mud or slurry with water which is removed at regular intervals and constitutes a sample. A great deal of care must be taken in order to produce an accurate sample.[5] The procedure that is used in forming a churn drill sample and the methods that are used in producing a workable record of each hole will be discussed later in this report.

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[4] McKinstry, <u>op</u>. <u>cit</u>., p. 70.

[5] McKinstry, op. cit., p. 70.

B. Diamond Drill

In diamond drilling, a ring-like annular bit set with diamonds is rotated at the end of a boring column, consisting of jointed steel rods. As the bit rotates, it cuts a cylindrical core of rock which passes through the bit into a core barrel. This core is recovered and constitutes a sample for examination. The jointed rods not only convey rotation and pressure from the drilling machine to the bit, but serve as a pipe to conduct water which washes away cuttings and ground up rock. These cuttings serve as a supplementary sample which can or cannot be combined with the core sample.[6]

In the past few years, two tremendous strides forward have been made in diamond drilling. These advances are -- the wire line core barrel and the oriented diamond bit.[7] The wire line core barrel and the oriented diamond bit have done much to increase the popularity of diamond drilling.

Before the wire line core barrel, the drilling rods were withdrawn at regular intervals and the core removed from the core barrel for examination and storage. With the wire line core barrel the core can be removed in a fraction of the time and still retain the core.[8]

The oriented diamond bit has decreased the cost

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[6] Jackson and Knaebel, op. cit., pp. 32-34.

[7] W.S. March, Mining Geology Lecture, Montana School of Mines.

[8] James D. Cumming, Diamond Drill Handbook (Toronto, Ontario, 1951), p. 260.

of diamond drilling greatly in that the bits now last much longer. The diamonds are set by hand in such a manner that the hardest and strongest axis of the diamond is subjected to the most strain and therefore last longer.[9]

C. Shot Drill

Shot drilling is like diamond drilling in that the bit is rotated by hollow rods, driven by an engine and gearing on the surface, but the cutting medium instead of set diamonds, consists of loose chilled shot fed into the rods with the wash water and rolling under the bit. Shot drill holes are usually of a larger diameter than diamond drill holes (some holes are five ft. in diameter) and therefore can give a more representative sample of the surrounding rock; however, considerable caution must be taken in order that chilled-shot does not salt the sludge sample if a sludge sample is used.

D. Hammer Drill

In hammer drills, the piston strikes the drill steel and motion is transmitted through the drill steel to the bit which remains in contact with the bottom of the hole except during a slight rebound. In some cases an anvil block is placed between the piston and the end of the drill steel. The drill steel is rotated before or during

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[9]March, op. cit.

each impact between the bit and the bottom of the hole.[10]

The use of hammer drills in sampling practices has been very successful in some cases. Pneumatically operated hammer drills of the type employed for drilling for underground blasting is used for sampling and exploration. The cuttings from the hole constitute the sample. The hammer drill is especially useful in sampling the walls of stopes to find the ore limit.[11]

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[10] R. Peele, Mining Engineer Handbook (New York, 1951), pp. 15-32.

[11] Jackson and Knaebel, op. cit., pp. 54-55.

# III. Churn Drilling

## A. Churn Drilling Equipment

Churn drills in common use today are made up in two principal sizes, both of which are portable and employ the same principal mechanical design. The smaller size is usually used for shallow holes. Depths of from 600 - 700 ft. can be reached under the best conditions. This small churn drill is the type that is commonly used for drilling blast holes in quarry and open pit mining. The larger size churn drill normally drills to depths of from 1000 - 1200 ft, and under favorable conditions, depths of 2000 ft. can be gained.[12]

A great variety of sources of power have been employed on the churn drill (steam, diesel, electric, gasoline), but the final choice of power is dependent upon local conditions and the whims of the drillers. "It is the opinion of some drillers that the internal combustion engine, due to the power lag, imparts a better "snap" to the cable than does the electric motor."[13]

## B. Operation Of The Churn Drill

### 1. Drilling

The drilling cycle of a churn drill is relatively simple. If the formation being drilled contains a great deal of water, the bit is simply lowered to the bottom

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[12] McKinstry, op. cit., p. 73.

[13] McKinstry, loc. cit.

of the hole and drilling is begun. If the formation is dry, water is lowered to the bottom of the hole and dumped. The supervising engineer should take a great amount of precaution to see that the drillers do not run water down the hole from the collar, because this will cause an inaccuracy of sample which will be explained later in this paper.[14]

Drilling is performed by a rhythmic raising and dropping of a relatively blunt bit on the bottom of the hole. The rock is crushed rather than chipped by the impact of the bit. At the start of the downward motion the bit is allowed to fall freely until it approaches the bottom of the hole. At this point, the cable is "snubbed" and the bit "snaps" back. The "snap" of the cable is considered of extreme importance in churn drilling. "The driller adjusts the speed of the cycle and the rate at which the cable is fed into the hole by judging the "snap" as he holds his hand on the cable."[15]

It is thought that the ratio of foot-pounds necessary to crush the rock, to the total theoretical energy developed by the falling drill tools, gives a good means of evaluating the efficiency of the drill. Studies have been made of the factors affecting the efficiency of

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[14] March, _op. cit._

[15] McKinstry, _op. cit._, p. 74.

a churn drill. If a thorough study of these factors and their relationships to the rock being drilled is made, a maximum of efficiency can be obtained for any particular churn drill. These factors are as follows:[16]

(a) Drillability of the rock itself.

(b) Weight of drill tools.

(c) Length of stroke.

(d) Number of strokes per minute.

(e) Diameter of bit.

(f) Amount of drilling water added periodically.

(g) Specific gravity of drilling sludge.

(h) Energy developed by the falling tools that is dissapated by the buoyant effect of the drill sludge and by friction.

(i) Friction that is developed in forcing the sludge below the bit upward through the watercourses in the bit as the bit falls.

2. Bailing

In most cases, the common practice in the West is, after every 5 ft. depth of hole has been drilled, to hoist the bit above the collar and lower the bailer into the hole on a light cable. The bailer is filled with drill cuttings (sludge), hoisted to the surface, and discharged.

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[16] J.R. Thoenen and E.J. Lintner, Churn Drill Performance (Washington, 1947), p. 3.

This process, known as bailing, is probably the most fruitful source of unreliable samples and at the same time the hardest operation to carry on in such a way as to give good samples. There are three important factors which tend to cause poor sampling results which will be discussed below: failure of drillers to clean the hole, the mechanical construction of the bailer, the knocking of foreign material into the sludge.[17]

a. Failure of Drillers to Clean the Hole

The bailing operation as done in prospect drilling is a fairly slow one -- especially so when the hole is deep. The drillers are anxious to "make footage" and as a result hate to spend any more time in bailing than is absolutely necessary to proceed with drilling again. As a result, the drillers leave 10% or more of the sludge in the hole. This sludge goes into the next sample so it is not lost altogether; however, if there is a difference in ore content between the two intervals, it will salt up or down, as the case may be, the sample from the lower interval. The only remedy for this fault is to provide careful supervision of the bailing by someone in a position to enforce careful work.[18]

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[17] Frederick G. Moses "The Sampling of Churn-Drill Prospect Holes" The Engineering and Mining Journal, Vol. C (August 21, 1915) p. 301.

[18] Moses, loc. cit.

b. <u>The Mechanical Construction Of The Bailer</u>

The dart valve type bailer is the most commonly used bailer because it is sturdy and functions easily. "The bailer is so built that the valve in the bottom of the instrument is opened by the weight of the valve and the sludge above will close the valve."[19] A diagram of the dart valve type bailer is shown in Fig. 1 of the appendix. The dart valve bailer is so constructed that it is impossible to get the amount of sludge equal to the length of the bailer into the bailer. This leaves a small amount of sludge in the bottom of the hole; however, unless there is a great difference in the assays of the two adjacent samples there will be no appreciable error in the sample taken. A possible remedy for the difficulty encountered due to the mechanical construction of the bailer is to progressively dilute the sludge. According to Moses the following procedure should be taken. "After all of the sludge that can possibly be taken out with the dart valve bailer is extracted, two or three buckets of water are thrown into the hole. The bailer is then run into the hole and worked up and down in order to mix the newly added water and the sludge that had been left in the hole by the bailer. The bailer is now pulled from the hole and emptied. Of course, the total amount of material, sludge plus water, is the same as the previous

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[19] Moses, *op. cit.* p. 301.

amount of sludge, but the total amount of solid matter is less because of the dilution caused by the water that was added to it."[20] The author of this paper disagrees with this in that the water should be lowered to the bottom of the hole in the bailer. Water that is poured down the hole will wash loose wall rock down into the sample and salt the sample.

c. The Knocking Of Foreign Material Into The Sludge

One of the greatest sources of error in churn drilling is from the dropping of material from the walls of a hole that is caving slightly. The only sure remedy for caving is to case the hole. Casing a hole is a laborous and difficult operation, and if caving is not to such an extent that it interferes with drilling operations, the drillers are not likely to report the caving. Unless a great amount of supervision is given and reliable drills are obtained the sample is bound to be caved in one way or another, depending upon the character of the caved material. A churn drill hole is most likely to cave in a brittle sulphide area and is not likely to be noticed unless watched carefully.[21]

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[20]Moses, op. cit., p. 301.

[21]Moses, op. cit., pp. 301-302.

3. Casing

It would be a rare mineral deposit that occurred so firm that the holes did not slough while the hole was being drilled. Fault structures and zones of alteration are almost always encountered. The formation itself may be too soft to support itself or the formation may be reactive with air and water to such an extent that spalling occurs. Also material can be knocked into the hole when the string of tools is lowered into the hole after the bailing has been completed. When the drilling tools are rapidly lowered into the hole, they will vibrate back and forth, striking the walls of the hole, and knock off pieces of wall rock.[22]

The casing itself consists of lengths of iron or steel pipe, of smaller diameter than the hole, which are fastened together and lowered down the hole to its bottom. When the hole is completely cased, drilling is continued with the next smaller bit size. If the hole again caves, a string of smaller diameter casing is telescoped within the next. If a deep hole is required in "bad" ground it usually requires many strings of casing and a reduction to a very small diameter at depth and therefore a less reliable sample at depth.

If a hole enters a zone of "bad" ground which quickly caves, casing is put down to the bottom of the hole.

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[22]Moses, op. cit., p. 301.

When drilling is resumed the casing will usually follow closely to the bit until firm rock is reached.[23]

4. Taking the Sample

The consistency of the sludge is an important factor in churn drill sampling. If a thick sludge is obtained, the sludge passes through the splitter with difficulty and additional water is required to wash the sludge through the splitter. If additional water is used the water tends to separate the heavy and light minerals. When the driller hoists the bit to the collar of the hole, he examines the sludge clinging to the bit. If the sludge appears too thick he dilutes the sludge at the bottom of the hole with water lowered in the bailer. In this manner, a thin sludge, that will pass through the splitter, is obtained. However, if the valuable mineral is a very heavy one, the heavy minerals will tend to settle out in a thin sludge. Therefore, a good deal of study must be done before the proper sludge consistency is determined.[24]

The procedure used in sampling is to discharge the bailer into a launderer which conveys the sludge to the point where it is sampled. The launderer of course is of sufficient size to avoid runover when the large sized bailers are used. These launderers are usually built from 2x12 in. planks and vary in length. They are sometimes lined

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[23] McKinstry, op. cit., pp. 75-76.

[24] McKinstry, op. cit., p. 77.

with steel plates to facilitate cleaning and thick steel plates are used to protect the launderer when the bailer is dropped into them.

Common practice in churn drill sampling employs a series of Jones samplers mounted at the downhill side of the launderer. The Jones splitter successively halves the sludge as it pours through the tiers of riffles. Since each tier of riffles cuts the sample in half, the size of the resulting sample is controlled by the number of tiers and any size may be obtained. A diagram of the common arrangement used in placing the launderers and splitters is shown in Fig. 2 of the appendix. The finished samples to be used for chemical and / or geological investigation are sent to the laboratory as either wet or dry samples depending upon the local arrangements.[25]

5. Handling the Sample

The methods of handling churn drill samples are many and varied; however, the general procedure and precautions to be taken are shown below as given by Moses.

"When a hole is deeper than, say 400 ft. the sludge will often contain gases dissolved in it. These gases are principally $CO_2$ and $H_2S$. During the process of drying a sample of this kind, these gases will be expelled. As the gases are driven from the solution by the heat, they will cause foaming, to a greater or lesser extent, and at

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[25] W.R. Grunow, "Churn Drill Prospecting at Morenci, Arizona." The Engineering and Mining Journal, Vol. CI (June 3, 1916) pp. 971-972.

the same time carry some of the finer of the sulphides to the surface of the liquid with them. If the pan in which the sample is being dried is too full, some of this foam may bubble over the side of it, and cause the loss of some of the fine sulphides, which will cause a low assay. There are two remedies for a sample that acts in this manner; use a pan that is large enough so that the danger of boiling over is avoided, and dry it over a slow fire.

There is one point that must be watched when sacking any kind of fire-dried sample. In the drying process the agitation due to boiling will naturally carry the heavier pieces in the sample to the bottom. The foam mentioned before will also be dried on the surface of the cake and a good deal of it will stick around the edges of the pan just at the top of this cake. Great care must be used when sacking a sample to which these two things have happened to see that the pan is scraped thoroughly, both sides and bottom, to loosen all of this material and get it into the sample. This material will carry the high grade, if any, which makes it doubly important."[26]

The above considerations deal with chemical samples only. When geological samples are needed from the same interval as the assay samples, a different procedure is taken. "A geological sample is simply a portion of

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[26] Moses, op. cit., p. 303

the sludge from which all of the clay and mud has been washed." A convenient way of taking this sample is to save and wash the discard from the last splitting of the assay sample. This material is then dried, labeled, sacked, and sent to the geologist."[27] A great deal of care should be used in preparing a geological sample so that a good mineralogical representation is given.

C. Records and Logs

It has been the standard practice for many years to compile a composite log showing the pertinent information acquired from the drilling of each hole. The logs are drawn to scale, and the various data plotted in their appropriate places. As much detail that is possible to determine is plotted, because failure to plot some data may result in having to drill a new hole years later. Information making up a complete log may be grouped as follows: (1) engineering (2) assaying (3) geological (4) metallurgical (5) operational.

The advantages of keeping churn drill records on a standard, easy to handle, composite, log far outweigh any system where different type of information is kept separately. An engineer using churn drill data desires to have all information readily at hand and in an easy to understand form. When an engineer must search through a complex filing system to obtain each additional piece of information about each churn drill hole, his efficiency is cut down and the quality of his work is very likely to drop. Two sample forms are shown in Fig. 3 and Fig. 4 of the appendix. Fig. 3 is a form that was in use in 1924 [28] and Fig. 4 is a form that is presently in use by Anaconda Copper Mining Company in Butte, Montana.[29]

D. Determining the Structure

The main purpose of churn drilling in prospect drilling is to give assay values of the rock. The second major purpose is to decipher major structural features of the district. Boundaries of major rock units can be detected through examination of the sludge. Large faults can be identified through a careful panning and examination of the sludge. Mineralogical changes can be detected such as passage from the oxide zone to the zone of secondary enrichment and from that to the primary ore zone. Percentages of insoluble residue can be used in correlating different formations soluable in acid. Unfortunately most minor geological information is lost in churn drilling.

Additional information from churn drill holes can be obtained through use of special devices. Among these

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[28] J.E. Harding, "Information Obtainable From Churn-Drill Sampling" Engineering and Mining Journal-Press, Vol. 117 (March 29, 1924) pp. 523-527.

[29] Bill Skinner - Ex-Sampler for A.C.M.

[30] McKinstry, *op. cit.*, p. 81.

special devices are: (1) graphs of resistivity and self-potential at successive depths (2) a sample taking cylindrical bullet fired into the wall from a gun suspended in the drill hole (3) a camera operated within the bore-hole.[31]

E. Cost and Speed

The costs and speed of churn drilling vary between churn drills and locations. In general, it can be said that costs and speed of churn drilling varies depending upon:[32] "(1) hardness of the ground, extent of its fracturing, and its ability to stand without caving; (2) the care and manner in which the hole is cased in order to ensure reliable samples; (3) the speed with which casing can be recovered, and the rig can be moved to a new set-up; (4) the diameter of the hole and the depth to which it is drilled; (5) the manner of sampling and the special precautions taken, and (6) the skill and experience of the drill crew and foreman in the particular district being explored." These factors vary widely from place to place.

Due to changing economic conditions and the varying factors affecting the cost of churn drilling it is nearly impossible to set one definite cost per foot of hole. Therefore no numerical costs will be given in this paper.

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[31] McKinstry, op. cit., pp. 78-79.

[32] McKinstry, op. cit., p. 81.

F. Engineers Duties

An engineer in charge of a drilling campaign should be given unrestricted authority to direct drilling if he is to be held responsible for the correctness of results. A responsible engineer should see that the drilling campaign gives a maximum of results in the most economical way possible. He should see that a great number of holes are drilled to obtain information that a few well placed holes could have given, and at the same time he must see that nothing is missed by too few holes. It is the duty of the engineer to decide upon a flexible spacing of holes in order to handle anything that may be encountered in drilling. Also he should supervise the taking and handling of samples at the drill, in the laboratory, and during interpretation.

# IV. DIAMOND DRILLING

## A. Diamond Drilling Equipment

The use of diamond drills date back to the ancient Egyptians who used tubular drills set with gem stones for boring short holes in the construction of the pyramids. The ancient drills were powered by hand and probably drilled holes to a depth of only a few inches.[33]

Since the days of the Egyptians, it remained until 1864 before Rudolph Leschot, a French engineer, again employed the principle of the diamond drill to mining. Diamond drilling machinery and methods have rapidly improved since that date until they have developed into the efficient machine that is seen in nearly every mining camp throughout the world.[34]

Diamond drills in use today can be divided into two major groups: mechanical feed as used on most small power rigs and the hydraulic feed as is used for most larger drills. Considerable difference of opinion exists as to the relative merits of each type of mechanism and perhaps each type of mechanism is correct for a certain type of job. "For any given setup, screw feed gives a constant advance and records the varying pressure on the bit, thus

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[33] Cumming, _op_. _cit_., p. 1

[34] C.H. Hitchcock "Diamond Drilling Practice" _Canadian Institute of Mining and Metallurgy and the Mining Society of Nova Scotia Transactions_, Vol. 36, 1933, p. 253.

apprising the runner of slight differences in hardness of rock, and of presence of thin seams and small crevices. This information is often invaluable when the core is much broken and its record consequently incomplete. But, in strata of frequently varying hardness, it is necessary to run through soft strata at reduced speed, so that the bit may not be damaged on meeting a hard stratum. With hydrolic feed the pressure is constant, and rate of advance varies more or less automatically as hardness of the rock varies. Thus danger to the bit in passing from soft to hard rock is lessened. The runner of the hydrolic - feed drill can instantly take advantage of changes in the formation, varying the rate of advance, within the limits imposed by the rock, merely by turning a valve. Three different speeds are the limit with screw feed, unless gears are changed."[35]

Recently portable diamond drills have been put on the market weighing less than 100 lb. these drills can be carried on a man's back and packed into prospects that could not be sampled by any other means. These portable drills or drills similar to these will probably play an important part in prospect drilling in the future.

B. Operation of the Diamond Drill

1. Drilling

The principle of diamond drilling is based upon

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[35]Peele, _op_. _cit_., pp. 9: 49-50.

the extreme hardness of the diamond which enables it to abrade or cut all minerals in the earths crust. The diamond drill consists of a power unit rotating a tubular bit, which is set with diamonds. The bit and an attached core barrel are rotated at a high speed under a controlled pressure. Water is pumped to the bit through hollow steel, flush-jointed rods through which water is pumped to cool the bit and remove the rock cuttings.

As the bit advances, a cylindrical core of rock passes into the core barrel where it is held and kept as a sample. The cuttings which are swept to the surface with the rising water are collected in a settling box for sampling.[36]

2. The Bit

In the early years of diamond drilling, drill bits were set almost exclusively with black diamonds or carbons. The price of diamonds rapidly raised as other industrial uses for diamonds came into being until, in 1929, the price reached a peak of about $180 per carat. As could be expected, this price restricted the use of diamond drills in industry to such places where core-drilling was absolutely necessary.

Recently, efficiency and costs have been improved by using small drilling bortz. ("Form of diamond ranging

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[36] Cumming, op. cit., pp. 17-19.

from clear to opaque and in many varying shades and colors, made up of sub-microscopic drystals with an irregular or radiating structure")[37] The faces of the bit are set mechanically with the bortz. Mechanical setting of bortz is much cheaper than the hand setting of the larger stones and it gives a finished product of much improved quality. Small drilling bortz has been responsible not only for the construction of smaller and lighter weight drilling machines, which its use permitted.

Another type of bit, that has recently come into use, is made by heating a mixture of powdered tungsten carbide, powdered metallic cobalt, and bortz in a mold under pressure. A hard matrix impregnated with diamonds is produced. Drilling must be carried out under high pressures with this type of bit.[38]

Another recent advance to diamond drilling has been the development of the oriented diamond bit. This bit holds its gauge much longer than ordinary types of bits and probably has a good effect towards core recovery. In this bit, the diamonds are oriented in such a manner that the strong axis of the diamond does the cutting.[39]

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[37] Cumming, op. cit., pp. 480-481.

[38] Cumming, op. cit., pp. 70-73.

[39] March, op. cit.,

Below in Table 1 is shown a classification of diamonds for drilling:[40]

CLASSIFICATION OF DIAMONDS FOR DRILLING

| Type of Diamond | Approximate No. Stones Per Carat | Approximate No. Stones Per Bit EX Size | Main Source | Used Mainly For |
|---|---|---|---|---|
| Bortz | 8 to 125 | 60 to 350 | S. Africa No. Africa Brazil | General drilling work including hard rock |
| Congo | Same as above for better grade stones. | | Belgian Congo | General Drilling |
| Carbon Carbonado Black Diamond | From 2 to 3 carats each and smaller as worn down | 4 to 40 | Brazil | For very hard and broken ground |
| Fragmented Bortz | 14 to 30 mesh and up to 20 per carat | Matrix impregnated with crushed diamond fragments along with small whole diamonds | Crushing bortz from Belgian Congo and some sources as bortz | Blast hole core drilling and extremely hard fine-grained formations Iron ore and iron formations |

[40] Cumming, op. cit., p. 79.

3. The Core Barrel

At the lower end of the line of drill rods, is the core barrel which is a cylindrical chamber for receiving and retaining the core as drilling progresses. Core barrels can be either of two general types: the single tube or the double tube. Figs. 5 and 6 in the appendix show diagrams of the single tube and the double tube core barrel.[41] A modification of the double tube core barrel that is frequently used in very broken or friable ground is the ball bearing, swivel type, double tube core barrel. This core barrel is so built that the inner and outer tubes rotate independently of each other.

Exceptional increases in drilling rates have been climed from a new type of core barrel known as the wire line core barrel. When obtaining cores by this method, the drill pipe is left in the hole and the core tube is pulled by a wire line and replaced in the core barrel when emptied. A time footage graph prepared by Longyear Co., to compare the drilling rates of the wire line core barrel and the convential core barrel is given in Fig. 7 of the appendix.

4. Samples

a. <u>The Core</u>

The main object of diamond drilling is to obtain a core sample ra ther than a sludge sample. A core sample has many definite advantages over a sludge sample. "The

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[41]Cumming, <u>op</u>. <u>cit</u>., pp. 41-46.

structure of the rock formation is revealed, stratification may be studied, then sections may be made for petrographic work, and cores may be subjected to many physical tests."[42] Every economical precaution should be taken to insure as complete core recovery as possible. Some of the controllable factors making for poor core recovery are as follows:[43]

(1) small diameter of core
(2) vibration, or chattering, of the drill rods
(3) excess drilling speed
(4) erosion by circulating water
(5) grinding of the core by running with a blocked bit
(6) dropping core from the bit, which, if not picked up before the next run, must be chopped up and washed from the hole as sludge

As the core is removed from the core barrel, it is placed in a core box in the exact order that it is taken from the ground. Core boxes are usually 5 ft. or less long and are built with partitions running lengthwise between which the core fits snugly. A standard system for laying the cores should be adopted for any churn drilling program.[44]

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[42] Longyear, Robert D. "Recovering and Interpreting Diamond-Core-Drill Samples" Mining and Metallurgy, Vol. 10 (May 1937), p. 240.

[43] Longyear, loc. cit.

[44] Hitchcock, op. cit., pp. 269-275

Adequate facilities should always be provided for the storage and preservation of cores. The cores should be stored in well made boxes and clearly and permanently labeled. If at all possible, the cores should be stored in a separate fire proof building. It is advantageous to keep the cores at a constant temperature and humidity.[45]

The core from a diamond drill hole should be considered a permanent sample. Adequate facilities should always be provided to store cores, even if no possible use can be seen at the present. Some companies make a practice of saving one-half of their samples or selecting pieces one inch long to represent every change of formation in the hole. This practice is of questionable value. The cost of diamond drilling is high enough that adequate facilities can certainly be provided to preserve the complete and valuable cores, even if they are not of value at the present time.

b. The Sludge

Some mineral deposits are too "soft" to produce cores. When drilling proceeds through deposits or beds of this kind it becomes necessary to collect sludge as well as core samples. The general practice is to collect sludge where the core - recovery is poor and when the core samples are good -- not to bother with the sludge. The practice of every throwing away a sludge sample is questionable in value since each sample that can be collected is representative

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[45] March, *op. cit.*, p.

of something and should be put to use if at all possible.[46] In any case, the sludge samples should be used as a check on the core samples. If large discrepancies occur between the core and sludge samples the discrepancies may be caused by the following:[47]

(1) incomplete washing of the holes between runs

(2) loss of drilling water

(3) either salting or dilution from material higher in the hole

(4) overflow of fines from the sludge boxes

(5) adherance of metallic particles to greased rods

Fig. 8 in the appendix shows a diagram of a box that is commonly used to collect sludge samples during churn drilling operations.

c. Core Splitting

In order to preserve the core as a geological record and at the same time produce an assay of it, each section to be assayed must be split longitudinally. One half of the sample is sent to the assay office while the other half is preserved as mentioned previously.

Mechanical core splitters are on the market which would be economical if a great number of cores were to be handled. For short jobs a cold-chisel can be used. A great deal of skill and practice is needed before cores

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[46] March, op. cit.

[47] McKinstry, op. cit.p. 90

can be split correctly and properly so that the cores are not ruined in the splitting.

The practice of splitting the cores for assaying varies from mine to mine throughout the world. In some cases all of the cores are split and sent to the assay office. In other cases the cores are split only when the sludge samples show values. In still other mines the core goes to the assay office only when the cores show mineralization. Whether or not to split a core for assay depends mostly upon local conditions; however, it should be said in passing that it would be a terrible thing if an orebody were passed through not having a core assayed.[48]

d. Logging

The engineer who records diamond drill data should carefully examine each core before and after splitting because it is difficult to get structural angles from split cores. Wetting the core aids greatly in bringing out textures and other minute features that are not brought out in any other way. Each driller should keep a standard log containing a record of the hardness or softness of the ground and the places where the motion of the machine indicates that the core is being ground up.

In addition to the drillers log, an engineer's log should be kept on a standard form so that it may be filed with others. Also, each diamond drill hole should be plotted on a map using standard symbols. Fig. 9 of the

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[48] McKinstry, op. cit., pp. 86-87.

appendix shows a standard diamond drill assay record as recommended by E.J. Longyear Co.[49]

5. Combining Assay Returns

When mine operators combine core and sludge assays they usually do not fully realize the ratio of the sludge to the core. The tendency for most operators is to give undue importance to core assays while the sludge assays may be more important than the core assays because the sludge represents a larger volume of material from the sample intervals. Fig. 10 of the appendix shows sections illustrating the sludge-core ratio for the 4 standard diamond-drill bits.[50]

When core recovery is incomplete the sludge sample assumes a great importance. Calculations are then based on the assumption that the unrecovered part of the core was ground up and became a part of the sludge; therefore, the calculation must take into account the percentage of core recovery which may be estimated by one of the following methods:

(a) The pieces of core are fitted together and their combined length is measured.

(b) The core is weighed and compared with the weight of core that should be cut by a bit of the size used.

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[49] Longyear, op. cit., p. 242.

[50] Weller, J.M. "Interpretation of Sludge and Core Assays" Engineering and Mining Journal, Vol. 139 (July 1938) p. 37.

(c) In addition to the weight, the specific gravity of the core is determined by weighing in water and the diameter of the core is measured at frequent intervals. The recovery is computed by comparing actual weight with the estimated weight for 100% recovery, calculated from the volume and specific gravity according to the formula:"

$$\frac{\text{weight of core} \times 100}{(\text{Length of run})\ (\pi)\ (\text{diam } 1/2)^2\ (\text{sp. gr.})\ (62.5)}$$

When the percentage of core recovery has been calculated, the factors for computing the ratio of combination can be calculated from this and from the total volume of the hole. Tables and graphs are published for this purpose and Fig. 11 of the appendix shows a sample graph put out by E.J. Longyear Company. This graph is self explanatory, so it will not be discussed further here except to say that the method of using the graph is not valid unless the sludge recovery is 100% or nearly so.

Shown below is a complete calculation for an A X diamond drill hole. These calculations are taken from McKinstry's Mining Geology. One of the four methods given will be able to handle any situation run up against in diamond drilling.[51]

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[51] McKinstry, op. cit., pp. 93-96.

## Example of Methods of Calculation

Data: Length of run: 5 ft.

Bit A X - Core Assay = 0.50% Cu, Sludge assay 1.10% Cu

Sp. Gr. of Rocks: 3.00

| | Recovered | | | Assay |
|---|---|---|---|---|
| | Length | Weight | Percentage | %Cu |
| Core | 2 ft | 2.3 lb. | 40% | 0.50 |
| Sludge | | 9 lb. | 58.5% | 1.10 |

Percent Core Recovery = 2/5 = 40 %

Percent Sludge Recovery = 5(2.30 + 0.60 x 1.30 ) = 15.40

$$\frac{9}{15.40} = 58.5\%$$

The volume and weight factors for an A X bit would be calculated as follows:

| | Diameter | AreaCross Section | Vol.per ft. of length | Weight per ft of len. Sp. Gr. 3 | % of vol. of hole |
|---|---|---|---|---|---|
| Hole | 1 7/8" = 1.875" | 2.76 $in^2$ | 0.0192 $ft^3$ | 3.60 lb. | 100% |
| Core | 1 1/8" = 1.125" | 0.99 $in^2$ | 0.0069 $ft^3$ | 1.30 lb. | 36% |
| Sludge | | 1.77 $in^2$ | 0.0123 $ft^3$ | 2.30 lb. | 64% |

Method #1 -- Core and Sludge Recovery Complete

| | % of Vol of Hole | x Assay | = Product |
|---|---|---|---|
| Core | 36 | x 0.50% | = 18.0 |
| Sludge | 64 | x 1.10% | = 70.4 |
| | 100 | | 88.4 |

Average Assay $= \frac{88.4}{100} = 0.884\%$ Cu

Method #2 -- Sludge Recovery Complete

Core represents 40% of 36% of volume of hole or 14.40%. Therefore Sludge represents 100 - 14.40 = 85.6% of volume of hole.

| | % of vol. of hole | x assay | = Product |
|---|---|---|---|
| Core | 14.40% | x 0.50% = | 7.2 |
| Sludge | 85.6% | x 1.10% = | 95.2 |
| | 100.0% | | 102.4 |

Average Assay = $\frac{102.4}{100}$ = 1.024%

Method #3 -- Incomplete Sludge Recovery

| | Weight | x | Assay | = Product |
|---|---|---|---|---|
| Core | 2.3 | x | 0.50% = | 1.15 |
| Sludge | 9 | x | 1.10% = | 9.90 |
| | 11.3 | | | 11.05 |

Average assay = $\frac{11.05}{11.3}$ = 0.977%

Method #4 -- Incomplete sludge assay and also handles too large sludge assay.

Theoretical vol. x % of theoretical = product x assay = product
(Method 2) vol recovered

| | Theoretical vol. (Method 2) | x % of theoretical vol recovered | = product | x assay | = product |
|---|---|---|---|---|---|
| Core | 14.40 | x 100 | = 14.4 | x 0.50 | = 7.2 |
| Sludge | 85.6 | x 58.5 | = 50.0 | x 1.10 | = 55.0 |
| | 100.0 | | 64.4 | | 62.2 |

Average assay $\frac{62.2}{64.4}$ = 0.967%

A thorough understanding of the theory behind each method should be used before any one method is selected for calculations and experience gained through a study of regional characteristics should be used. An intelligent selection of calculations and intelligent calculations can do much towards blocking out ore or eliminating ground for further exploration.

6. Deviation of Holes

When drawing conclusions from diamond drill holes it is important to determine the extent of the hole in length and deviation. "The deviation is surveyed in angular deflection in amount and bearing; the amount relative to the intended initial direction and the bearing with respect to the local meridian or any other fixed reference work."[52] Experience has shown that deviation of holes is negligable in short holes but in holes over 200 ft. long and in holes measured in thousands of feet in length, the deviation may also be measured in thousands of feet. In some tests made concerning deviation it has been found that the amount of displacement is proportional to the square of the borehole length and it usually tends to describe a righthanded or clockwise curve. It has also been found that horizontal and inclined boreholes, particularly upward inclined holes, deviate sooner and to greater extent than verticle ones.[53]

There are many causes of borehole deviation and some of them are hard to detect; however, some of the most

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[52] Haddock, M.H. Deep Hole Surveys and Problems, p. 1

[53] Haddock, op. cit., pp. 1-8.

frequently encountered causes are listed below.[54]

(a) Incorrect centering at surface

(b) Alternating hardness of successive layers of hard and soft rock.

(c) Inclined strata

(d) Lack of rigidity in the rods

(e) The proximity of other boreholes

(f) Fissured strata

(g) Pressure on the rods

(h) Reduction of borehole diameter

(i) Oversetting the diamonds in the crown

(j) Weak core barrels and small holes

(k) Static electricity and magnetism of rods

7. Surveying Holes

Since few diamond drill holes are ever straight, it becomes important to determine exactly how much each hole deviates and exactly where each hole intersects a given structure. There is a great multitude of devices that have been made to determine deviation and probably all of the devices made their relative merits; however, only some of the most frequently used devices will be discussed here.

Perhaps the simplist device used in surveying drill holes for deviation from the verticle is the hydrofluoric - acid method. The apparatus used in this method consists of small wide-mouth bottles with rubber stoppers, a supply of hydrofluoric acid, a metal container for the

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[54] Haddock, op. cit., pp. 14-21.

bottles, and a goniometer. When in operation, the mechanism is lowered into the hole by a wire or attached to the end or in the middle of a string of rods. The acid is diluted according to the depth of the hole and the time required for lowering the container so that little etching takes place before the instrument reaches the desired place. The bottle is then left at the desired place long enough to allow the acid to etch a line on the glass in the position at which the liquid stands and thus give a record of the inclination of the hole. The container is then withdrawn, washed out, filled with water or a colored liquid and the angle of deviation is measured with a goniometer. Small errors due to capillary action are then made with the aid of charts provided for that purpose.

Another device that is commonly used in surveying drill holes is the Maas compass. The Maas compass consists of a device similar to the one mentioned above together with a small magnetic needle on a pivot attached to a cork which floats in gelatine. The gelatine and the hydrofluoric acid are in the same tube, separated by a rubber stopper. When the Maas compass is in operation the gelatine is heated in a bottle until it is liquid, then placed in the container, lowered to the proper point in the hole and allowed to sit and at the same time, hydrofluoric acid etches a line in the glass of the other end of the tube. From the position that the magnetic needle is in when the gelatine sets and the position of the etched line from the hudroflouric acid, deductions can be made about dip and azimuth of the hole.

Other methods commonly used in surveying holes are the photographic methods which employ a magnetic needle which bears radioactive material that registers the position of the needle on a photographic plate. It must be remembered however that whenever a magnetic needle is employed a great deal of error is likely to result due to local magnetic attraction. Errors due to magnetic attraction can be eliminated by using a gyroscopic compass instead of a magnetic compass.[55,56]

C. Deductions From Drill Samples

1. Grade

The primary purpose of diamond core drilling is to recover samples to be used for a chemical analysis, physical tests or visual inspection. In order for a sample to fulfill these purposes, information must be systematically recorded and honestly carried out. Provided that a drilling campaign is carried out carefully and systematically a sample from a diamond drill is similar in all respects to a moiled channel sample.[57] No channel sample can take as even a groove as the cylinder of material that is removed in the normal diamond drill sample.

Further, diamond drilling vertically eliminates

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[55] Peele, op. cit., pp. 9-63 -- 9-69.

[56] Hitchcock, op. cit., p. 262-263.

[57] Longyear, op. cit., p. 239

human error that may be incured in any other method of sampling. The samples taken in drilling have no favoritism towards richness or lean-ness, hardness or softness as would normally be the case in other methods of sampling.

A great deal of caution, however must be used in interpreting diamond drill samples. Some samples may be barren when they should show values, while others may show values where there are no values. In some cases, assay values have to be disregarded completely due to the erratic nature of the rock; however, the mineralogical nature of the vein-matter in the core may indicate whether or not a vein is worth developing.[58]

2. Vein Width

In drilling it can plainly be seen that the distance between vein walls is not the true vein width. Unless a drill hole intersects a vein at a right angle, a correction must be made before the true vein width can be found. If a drill hole intersects a vein at a small angle an erroneous impression of width would result if the vein were not investigated further. In order to get the true width of a vein the angle of intersection must be obtained.

The angle of intersection between the drill hole and the orebody can be obtained in one of two ways. In a deposit that cores well, the angle of intersection may be visible in the core itself. In some deposits this method may or may not be accurate. Only experience can determine

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[58]McKinstry, op. cit., p. 99.

this. The second method involves a calculation concerning several drill holes to determine the strike and dip of the vein and the known bearing and angle of inclination of the drill hole. From these calculations a very accurate determination can be made involving the angle of intersection.[59]

3. Structure

Another important use of the diamond drill is in securing information concerning structural information. The general procedure used in drilling purely for structure is to drill a series of holes in a set pattern so that the maximum amount of structure can be determined from the pattern. Of course most drill holes combine structural information and assay information.

If a particular structure can be identified in three different holes, its dip and strike can be calculated by the three point method as used in descriptive geometry. Most structural problems require at least three holes for solution, but two holes can do much toward solving the problem in that in some cases all but two or three solutions can be eliminated.

D. Cost and Speed

The speed and cost of drilling are roughly inversely proportional and vary directly with the nature of the rock. "Speed is affected by: kind of rock and surface covering;

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[59] McKinstry, op. cit., pp. 99-100.

[60] McKinstry, op. cit., pp. 100-103.

depth, direction, and situation of hole; quantity of water in hole; core requirements; labor, climate, and continuity of work; percentage of delays."[61] The type and condition of rock encountered in drilling perhaps is the greatest factor affecting speed. The rate of advance is higher in uniform speed. The rate of advance is higher in uniform rock than in alternating hard and soft strata.[62] Shattered and fissured rock generally plays an important part in delaying a drilling operation. Any delays encountered while drilling such as: loss of a bit, caving of the hole, plugging or cementing of the hole, or bouldery formations will cause the expenses of drilling to increase rapidly. Below is shown a table of drilling rates that could be considered relatively representative for different types of rocks.[63]

| No. of holes | Depth of holes, ft. | Progress per shift ft while driving | overall |
|---|---|---|---|
| 6 in limestone | 200-1000 | 28.6 | 17.2 |
| 4 in shale | 1000 | 33.1 | 21.1 |
| 6 in iron formation | 1200 | 10.1 | 7.2 |
| 3 in gypsum | 1000 | 22.6 | 13.3 |
| 4 in clay | 300 | 23.0 | 16.1 |
| 5 in taprock | 1200 | 12.1 | 9.3 |
| 4 in norite | 1000 | 18.4 | 12.6 |
| 2 in serpentine | 300 | 21.4 | 14.3 |
| 5 in basalt and granite | 1000 | 9.1 | 6.2 |
| 6 in porphyry | 600-2000 | 9.0 | 6.2 |

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[61] Peele, op. cit., p. 9-56.

[62] Jackson and Knaebel, op. cit., p. 33.

[63] Peele, op. cit., p. 9-56

So many variables are involved in diamond drilling that it is difficult to set up a definite price scale, especially under rapidly changing economic conditions. Peele gives costs ranging from $1 - $15 per ft. with a price of about $3 per ft. being about average. McKinstry sites a case where in Canada large mines report costs as low as $0.58 per ft. Costs as low as this have been shown in Mining Geology classes and Mining classes at the Montana School of Mines; however, these extremely low costs are the exception rather than the rule. Costs for diamond drilling can go so high as to be prohibitive.

E. Engineers Duties

An engineers duties in diamond drilling in general are very similar to those an engineer would have in churn drilling. Here again, an engineer should be given unrestricted authority to direct drilling if he is to be held responsible for the correctness of results. The engineer in charge should be able to place holes in whatever positions he chooses for the maximum amount of results. He should be able to direct the whole process of diamond drill sampling from the drill right through to storage and interpretation of the samples so as to get the most accurate results.

## V. HAMMER DRILLING

Pneumatically operated drills of the type that are used in normal mining operations are also employed for use in prospect drilling. In this type of prospect drilling cuttings from the hole constitute the sample much in the same way that churn drill cuttings constitute a sample. Hammer drilling can be subdivided into two distinct methods which are very similar. These two methods are: shallow drilling and deep drilling.

### A. Shallow Drilling

Shallow test-hole drilling is usually termed as any test hole drilling less than 22 ft. The work is performed with ordinary unjointed steel and is usually drilled dry, employing a canvas bag held around the collar of the hole to catch the cuttings.

The manner that a sample is taken and the amount of sample needed depends upon the purpose for which the sample is to be used. If just a visual inspection of the cuttings is all that is needed a great amount of care in taking samples is not needed, but if assays are to be made a great amount of care should be taken. As mentioned before a canvas bag is usually used to catch the cuttings, however, if the hole is drilled, powder boxes or a series of cans for decanting can be used.

Shallow test holes are usually limited to use for testing the walls of workings for additional ore in the hanging wall or the footwall or in search of the economic limit for mining. In some cases it has been found that channel samples are not reliable and that hammer drill samples provide the best assay information. The main advantage of shallow drilling methods is that fairly accurate samples can be taken in a working place using equipment already on hand. No special equipment need be hauled in and set up just to drill one or two holes.[64]

B. Deep Drilling

Deep test-hole drilling is usually termed as any test-hole drilling using steel sections 3 - 9 feet long connected by threaded sleeves. Threaded sleeves allow the steel to butt up against each other to take the compressive stress during the forward stroke and then the sleeves take the torsional and tensional stress during rotation and the back stroke.[65]

Long holes are always drilled wet, therefore it is not practical to use a canvas bag to catch cuttings. The most common practice for collecting cuttings is as follows. An auxiliary hole is drilled up into the main hole to intersect the main hole at a few inches. A pipe is fitted into the hole in such a manner that the water and

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64 J.B. Knaebel, Sampling and Exploration by Means of Hammer Drills, pp. 2-4.

65. Drullard, H.R. "Drilling Deep Holes with Hammer Drills and Sectional Drill Rods" Engineering and Mining Journal, Vol. 117, (March 1, 1924), pp. 384=386.

cuttings are drained into a recepticle which allows the cuttings to settle out and drain into another recepticle where the slimes settle out. Enough recepticles should always be used to insure that the slimes settle out, unless, the slimes assay the same as the coarses particles.[66]

There is some disagreement as to what angle from the horizontal gives the best samples. Authorities give angles ranging from 5° to 60°, however, the general consensus of opinion seems to point toward 10° as being the best. No authority gives any scientific reason why a certain angle would be best so therefore one could assume that the best angle is characteristic of the deposit.[67, 68]

The water pressure is also an important factor in hammer drill sampling. If not sufficient water pressure is used to wash the cuttings out of the hole, the hole of course would become clogged. If too much pressure is used the water may wash out fine vein matter that ordinarily would not be washed out. It has been found by some operators that a pressure of about 70 P. S. I. with a flow of about 3 to 5 G. P. M. is sufficient to wash the cuttings out of a hole 10° above the horizontal.[69]

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[66] Brown, R.K. "Exploratory Deep-Hole Drilling" <u>Compressed Air Drilling</u>, Vol. 31-32 (April 1956 pp. 1593-1594.

[67] Netzeband, W.F. "Prospecting With the Long-Hole Drill in the Tri State Zinc - Lead District" <u>Mining and Metallurgy</u>, Vol. 11 (June 1930) p. 295.

[68] Dobbel, C.A. "Deep-Hole Prospecting at the Chief Consolidated Mines" <u>American Institute of Mining and Metallurgical Engineers</u>, Vol. CXXII, pp. 677-684.

[69] Drullard, <u>op. cit.</u>, p. 385

Although no author on hammer drilling has mentioned the effect of oil used in drilling upon the assay results, there probably would be some effect due to the fact that some oil serve as flotation reagents. Whether this would salt the sample up or down is debatable, but it probably would have some effect. Fig. 12 of the appendix shows a diagram of a set up used in longhole drilling.

C. Interpreting Data

"Drill holes should be logged in accurate detail in the same general way as diamond or churn drill holes. Generally a driller's log and a geologist's log are kept, the former giving such information as location, course, and inclination of hole, dates started and stopped, depths, drilled each shift, bits used, samples taken (if taken by the operator), time lost in delays, and general remarks such as changes in formation, color of sludge, or hardness, fractured or broken ground noted by behavior of drill, loss of return water, and so on."

"The geologist's log should record the location, direction, depth of hole, and dates; feet of various formations penetrated, presence of gauge, broken ground, dikes, veins, contacts, and the like; description of rocks cut, assays where made; and similar data. It has been found possible in many instances to obtain a surprising amount of

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[70] Knaebel, op. cit., pp. 11-12.

geological information from careful study of the drill duttings; by making detailed records of such information at the time the study is made the results are preserved as a source of reliable information for the future."[70]

It should be stressed that nature of the information that can be obtained and the accuracy of the information obtained, depends to a large part on the character of the rock being sampled. The extent of the information that can be obtained remains unknown until sampling has been tried and followed through with exploration.

## VI. SHOT DRILLING

Principles used in diamond drill prospecting vary very little from shot drill techniques. Although shot drilling has found little use in the United States, it has been used extensively in South Africa. The only major use that shot drilling has found in America is its increasing use in shaft sinking. Shafts of quite large diameter have been sunk by placing the rotating mechanism down in the hole.

The rods used in shot drilling are considerably smaller than the bit which causes the ascending water to slacken in velocity above the bit and thus settle in a sediment tube or colyx.[71] Used up shot usually settles along with the drill cuttings which must be removed with a magnet before accurate assays can be made.[72]

Perhaps someday as the price of diamonds increases to such an extent, that diamond drilling becomes prohibitive, shot drilling will find an increasing use in prospect drilling.

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[71] Peele, op. cit., pp. 9-61 -- 9-62.

[72] Matson, H.T., and Wallis. G. Allan, "Drill Sampling and Interpretation of Sampling Results in the Copper Fields of Northern Rhodesia: American Institute of Mining and Metallurgical Engineers Technical Publication 373, p. 8.

## VII. PLANNING A DRILLING CAMPAIGN

### A. Choice of Drills

Whatever type of orebody being prospected for and whatever the purpose of prospecting is -- the choice of drilling methods, in general, is usually between churn drilling and diamond drilling. The actual choice between churn drilling and diamond drilling usually is determined by such factors as type of orebody, cost, speed, purpose of work, speed vs. cost and whims of the person in charge of the drilling campaign. If the drilling must be done underground, there is little doubt that diamond drilling would be best, but if the drilling is to be done on surface the churn drill should also be given serious consideration.[70]

Some of the factors that should be considered before a choice of drilling methods is selected are as follows:[71]

Comparison of Diamond and Churn Drills

| Diamond Drill | Churn Drill |
|---|---|
| 1. Can drill in any direction--downward, horizontal, inclined, and (from underground workings) upward | 1. Can drill only vertical downward hole. Usually Drills from surface, but can drill from underground when large station is prepared. |

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[70]Peele, op. cit., pp. 10-29 -- 10-47.

[71]McKinstry, op. cit., p. 108.

| | |
|---|---|
| 2. Core sample gives valuable geological information: texture of rock, distribution of mineral grains, altitude of bedding, clearage veinlets, etc., to axis of core. | 2. No core sample. Cuttings examined in laboratory give considerable information regarding nature of rock and mineralization. |
| 3. a. Sample is small, though shape and diameter are uniform. | 3. a. Sample more accurate insofar as size is larger. Shape and diameter more subject to variation. |
| b. In gold deposits gives good sample if core is good. | b. Large gold particles difficult to raise through though performance of bailer improved by thick mud and suction bailer. |
| 4. a. Slower than churn drilling under average conditions. | 4. a. Faster, at least up to 100 or 1200 ft. |
| b. Successful in hard rock. | b. Slow and expensive in really hard rock. |
| c. In fractured blocky ground gives incomplete core and slow progress. | c. Successful in fractured blocky ground. |
| d. Suffers "grief" and | d. Progress satisfactory |

| | |
|---|---|
| serious bit wear in poorly consolidated conglomerate, or soft rock with hard veinlets and nodules. | in conglomerate (if not too hard) and chert-bearing limestone. |
| e. Gives unsatisfactory core in unconsolidated material. | e. Gives good samples in unconsolidated material (sand, gravel and clay) |
| 5. Hole usually serves no purpose other than testing. | 5. Hole being large may serve for ventilation, drainage, or (in open pits) for blasting. |

In some cases it has been found most economical to use a churn drill for a certain part of a hole and then revert to the diamond drill to continue the hole. Of course, this method would only be economical when a great number of holes were to be drilled and the conditions were very bad.

B. Drilling for New Ore

1. Geometric Pattern

One of the ways to test a block of ground completely for new ore is to set up a pre-arranged geometrical pattern for the location of the holes. The geometric pattern has many definite advantages. The exact number of holes needed to sample the ground is known exactly. The costs for the drilling campaign along with the number of machines needed is known. This type of test, should not be used unless it is planned to be carried on to completion.

The habits of the ore in any district will determine the spacing that should be used in finding an orebody. If the characteristic orebodies of a district were of a certain width the holes should be spaced at a smaller interval in order to intersect every orebody. "If the oreshoots are long horizontally and short vertically, the holes may be spaced further apart horizontally than vertically. If on the other hand, the oreshoots have steep pitches, the spacing should be wide vertically and close horizontally."[74]

2. "Feeling Your Way"

Another way of testing a block of ground is to "feel your way" by letting the results of each hole determine the position of the next. The method of "feeling your way" into an orebody is much more flexible and is a good way to enter a region that is not known. This method is capable in giving more geological information than the geometric method if sound geological judgment is used. In some cases, it will be found advantageous to use a combination of both methods for a combination of the two methods may be better than either one above.[75]

## VIII. DRILLABILITY OF ROCKS

Practical experience gained in the drilling and bladting of rock teaches one to judge the drillability of rocks without knowing their proper names, chemical composition, or the class to which they belong. Men with many years of drilling experience are able to correctly judge the drilling speed of a given rock and not even be able to correctly explain why or how they came to make their decision on the drillability. Judging the drillability of rock is not an in-born talent that only a few are blessed with, but is is an art which anyone, by following a few simple rules of testing and observation can judge.

"The four drilling characteristics of rocks are (1) hardness, (2) texture, (3) fracture and (4) formation. Each one of these four drilling characteristics has five classifications which conform to the five classifications of the drilling conditions as shown in the rock chart. The object is to determine the drillability of an unknown rock by placing it in the proper classification of one of the five drilling conditions of (1) fast (2) fast average (3) average (4) slow average (5) slow. Then by knowing the average drilling speed of any particular rock drill, the drilling speed of the unknown rock can be closely estimated."[74]

The rock chart as used in determining drilling

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[74] Davey Compressor Company, Drillers Handbook on Rock, (Kent, Ohio, 1955) pp. 47-48.

conditions is shown in Fig. 13 of the appendix. By use of this chart a theoretical drilling speed for the rock may be determined. A point system is used in this determination. For each rock characteristic a number is taken from the bottom of the chart. The sum of the numbers from the five drilling characterists determine the drilling speed. A total of 32 is fast, 16 is average fast, 12 is average, 8 is average slow and 4 is slow. When the total falls between any of these classifications good judgment must be used to cetermine exactly what speed to choose.

# IX. CONCLUSION

As ore deposits become mined out and as new obvious surface deposits become more scarce, new methods of prospecting will have to be resorted to, to find ore deposits deep in the earth that have no surface expression. Among the methods that will be employed are -- geophysical prospecting, geochemical prospecting, and prospect drilling.

Prospect drilling will always be in the forefront as a method of prospecting because it is the only way that samples may be taken from great depths at a reasonable cost when no other method of access is available. Prospect drilling will not only be used to explore virgin ore deposits, but also to extend known ore deposits. As ore deposits are extended vertically or laterally, drilling programs are being used to guide the mining programs.

Perhaps as drilling machinery improves, prospect drilling will come even more to the forefront as a method of prospecting.

X. Appendix

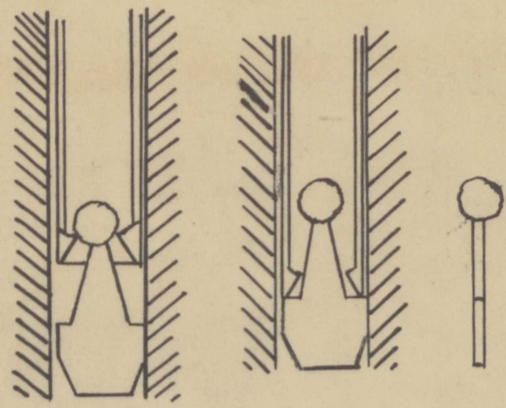


Fig.1. Dart Valve Bailer

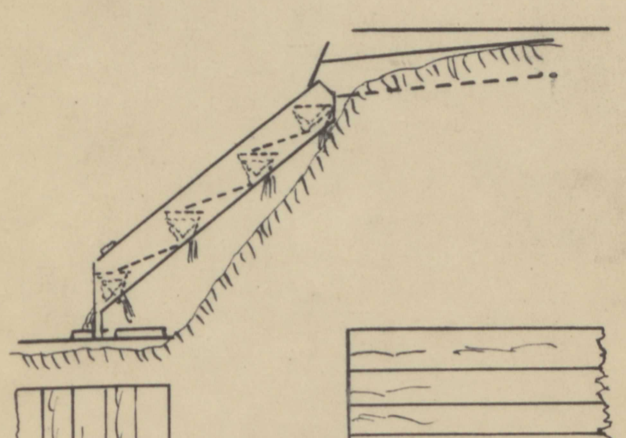
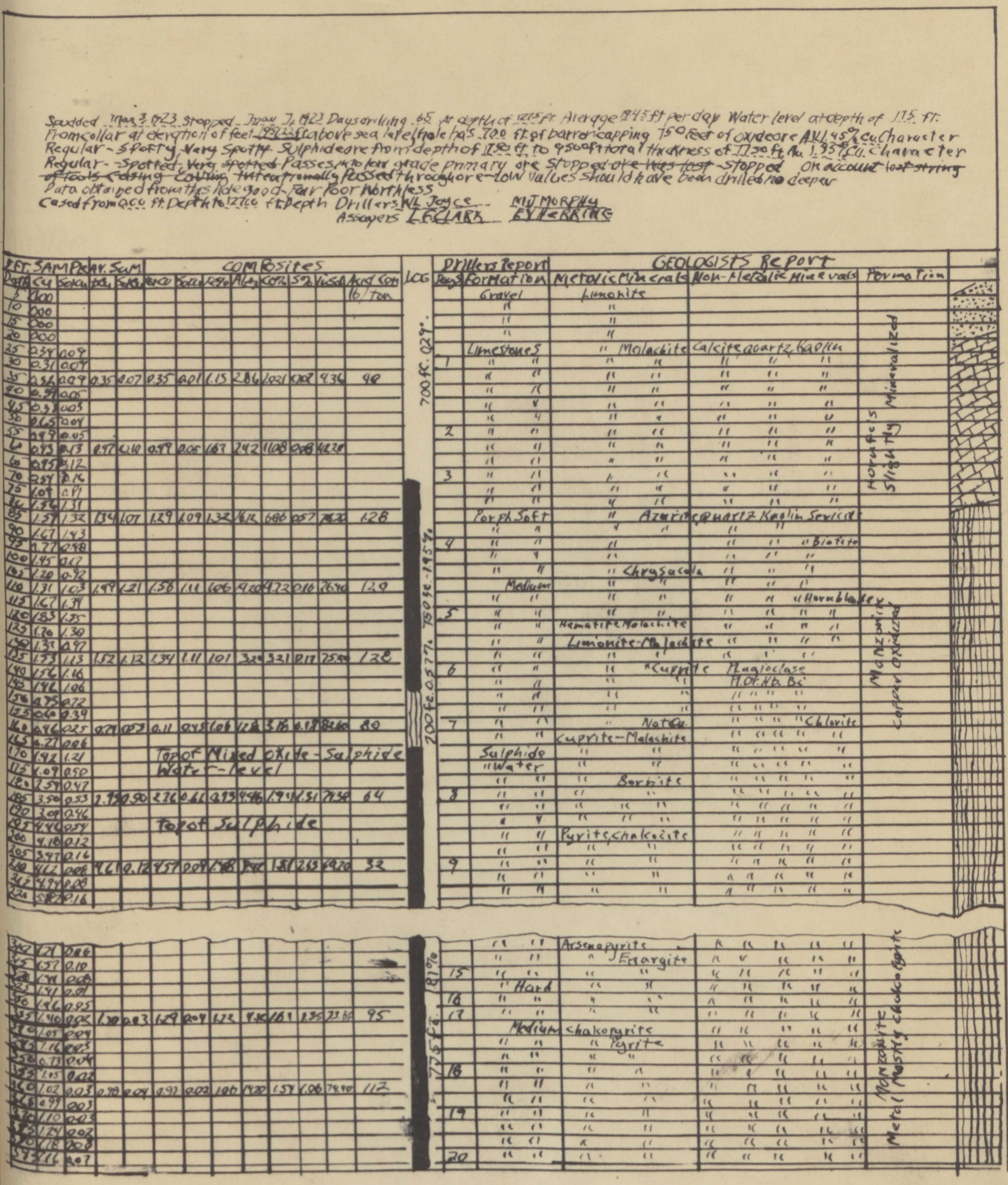


Fig.2. Arrangement For Automatic Sampling



Spudded May 3, 1923 Stopped Jury 7, 1923 Days drilling 65 At depth of 1275 ft. Average 19.45 ft per day Water level at depth of 175 ft. From collar at elevation of feet 1959.22 ft above sea level. Hole has 70.0 ft of barren capping 750 feet of oxide ore Av. 1.45% Cu. Character Regular - Spotty, Very Spotty. Sulphide ore from depth of 1150 ft. to 950.0 ft total thickness of 1150 ft. Av. 1.95% Cu. Character Regular - Spotted, ~~Very spotted~~ Passes into low grade primary ore Stopped ~~ore was lost~~ Stopped On account ~~lost string of tools Casing Caving~~ ~~intentionally~~ Passed through ore - Low values should have been drilled no deeper
Data obtained from this hole good - Fair Poor Worthless
Cased from 0.00 ft. Depth to 1276.0 ft. Depth Drillers W.L. Joyce   M.J. Morphy
Assayers L.E. Clark   E.Y. Herring

| 5 Ft. Samples | | | Av. Sam | | Composites | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth | Cu | Sol Cu | Cu | Sol Cu | Tot Cu | Sol Cu | Fe% | $Al_2O_3$ | CaO% | S% | Insol | Acid Con lb/ton |
| 5 | 0.00 | | | | | | | | | | | |
| 10 | 0.00 | | | | | | | | | | | |
| 15 | 0.00 | | | | | | | | | | | |
| 20 | 0.00 | | | | | | | | | | | |
| 25 | 0.34 | 0.09 | | | | | | | | | | |
| 30 | 0.31 | 0.09 | | | | | | | | | | |
| 35 | 0.36 | 0.09 | 0.35 | 0.07 | 0.35 | 0.01 | 1.15 | 2.86 | 1.031 | 0.02 | 4.36 | 48 |
| 40 | 0.59 | 0.05 | | | | | | | | | | |
| 45 | 0.37 | 0.03 | | | | | | | | | | |
| 50 | 0.65 | 0.04 | | | | | | | | | | |
| 55 | 0.99 | 0.05 | | | | | | | | | | |
| 60 | 0.93 | 0.13 | 0.97 | 0.10 | 0.99 | 0.05 | 1.67 | 2.42 | 11.08 | 0.08 | 42.20 | |
| 65 | 0.95 | 0.12 | | | | | | | | | | |
| 70 | 0.54 | 0.16 | | | | | | | | | | |
| 75 | 1.09 | 0.91 | | | | | | | | | | |
| 80 | 1.56 | 1.31 | | | | | | | | | | |
| 85 | 1.57 | 1.32 | 1.34 | 1.07 | 1.29 | 1.09 | 1.32 | 16.12 | 6.86 | 0.57 | 78.20 | 128 |
| 90 | 1.67 | 1.43 | | | | | | | | | | |
| 95 | 1.77 | 0.98 | | | | | | | | | | |
| 100 | 1.45 | 1.17 | | | | | | | | | | |
| 105 | 1.20 | 0.92 | | | | | | | | | | |
| 110 | 1.31 | 1.03 | 1.49 | 1.21 | 1.56 | 1.11 | 1.06 | 14.20 | 4.72 | 0.16 | 76.40 | 129 |
| 115 | 1.67 | 1.34 | | | | | | | | | | |
| 120 | 1.83 | 1.55 | | | | | | | | | | |
| 125 | 1.70 | 1.30 | | | | | | | | | | |
| 130 | 1.37 | 0.97 | | | | | | | | | | |
| 135 | 1.53 | 1.13 | 1.52 | 1.12 | 1.34 | 1.11 | 1.01 | 3.20 | 3.21 | 0.17 | 75.30 | 128 |
| 140 | 1.56 | 1.16 | | | | | | | | | | |
| 145 | 1.46 | 1.06 | | | | | | | | | | |
| 150 | 0.75 | 0.72 | | | | | | | | | | |
| 155 | 0.60 | 0.39 | | | | | | | | | | |
| 160 | 0.46 | 0.25 | 0.71 | 0.57 | 0.11 | 0.45 | 1.06 | 1.28 | 3.16 | 0.18 | 82.60 | 80 |
| 165 | 0.27 | 0.06 | | | | | | | | | | |
| 170 | 1.42 | 1.21 | | | Top of Mixed Oxide - Sulphide | | | | | | | |
| 175 | 1.09 | 0.50 | | | Water - level | | | | | | | |
| 180 | 2.54 | 0.47 | | | | | | | | | | |
| 185 | 3.50 | 0.53 | 2.95 | 0.50 | 2.76 | 0.61 | 0.93 | 4.96 | 1.91 | 1.31 | 79.50 | 64 |
| 190 | 3.09 | 0.46 | | | | | | | | | | |
| 195 | 4.40 | 0.54 | | | Top of Sulphide | | | | | | | |
| 200 | 4.18 | 0.12 | | | | | | | | | | |
| 205 | 3.47 | 0.16 | | | | | | | | | | |
| 210 | 4.12 | 0.08 | 4.61 | 0.12 | 4.57 | 0.09 | 1.58 | [illegible] | 1.81 | 2.63 | 79.20 | 32 |
| 215 | 4.94 | 0.08 | | | | | | | | | | |
| 220 | 5.82 | 0.16 | | | | | | | | | | |
| 310 | 1.21 | 0.06 | | | | | | | | | | |
| 315 | 1.57 | 0.10 | | | | | | | | | | |
| 320 | 1.44 | 0.08 | | | | | | | | | | |
| 325 | 1.41 | 0.09 | | | | | | | | | | |
| 330 | 1.46 | 0.95 | | | | | | | | | | |
| 335 | 1.40 | 0.05 | 1.30 | 0.03 | 1.29 | 0.04 | 1.23 | 4.45 | 1.61 | 1.35 | 73.60 | 95 |
| 340 | 1.05 | 0.04 | | | | | | | | | | |
| 345 | 1.16 | 0.05 | | | | | | | | | | |
| 350 | 0.73 | 0.04 | | | | | | | | | | |
| 355 | 1.05 | 0.02 | | | | | | | | | | |
| 360 | 1.02 | 0.03 | 0.98 | 0.04 | 0.97 | 0.02 | 1.06 | 14.20 | 1.54 | 1.06 | 74.40 | 112 |
| 365 | 0.99 | 0.03 | | | | | | | | | | |
| 370 | 1.10 | 0.03 | | | | | | | | | | |
| 375 | 1.24 | 0.02 | | | | | | | | | | |
| 380 | 1.18 | 0.08 | | | | | | | | | | |
| 385 | 1.16 | 0.07 | | | | | | | | | | |

LOG: 700 ft. 0.29% · 750 ft. 1.95% · 200 ft. 0.57% · 775 ft. 1.81%

| Drillers Report | | Geologists Report | | |
|---|---|---|---|---|
| Days | Formation | Metallic Minerals | Non-Metallic Minerals | Formation |
| | Gravel | Limonite | | |
| | " | " | | |
| | " | " | | |
| | " | " | | |
| | Limestones | " Malachite | Calcite, quartz, Kaolin | Hornfels Slightly Mineralized |
| 1 | " " | " " | " " " | |
| | " " | " " | " " " | |
| | " " | " " | " " " | |
| | " " | " " | " " " | |
| | " " | " " | " " " | |
| 2 | " " | " " | " " " | |
| | " " | " " | " " " | |
| | " " | " " | " " " | |
| 3 | " " | " " | " " " | |
| | " " | " " | " " " | |
| | " " | " " | " " " | |
| | Porph Soft | " Azurite | Quartz Kaolin Sericite | |
| | " " | " " | " " | |
| 4 | " " | " | " " " Biotite | |
| | " " | " | " " " | |
| | " " | " Chrysocolla | " " " | |
| | Medium | " " | " " " | |
| | " " | " " | " " " Hornblende | Monzonite Copper Oxidized |
| 5 | " " | " " | " " " " | |
| | " " | Hematite Malachite | " " " " | |
| | " " | Limonite-Malachite | " " " " | |
| | " " | " " | " " " | |
| 6 | " " | " " Cuprite | Plagioclase | |
| | " " | " " | Pl. Or. Hb. Bi. | |
| | " " | " " | " " " " | |
| | " " | " " | " " " " | |
| 7 | " " | " Nat. Cu. | " " " " Chlorite | |
| | " " | Cuprite-Malachite | " " " " " | |
| | Sulphide | " " | " " " " " | |
| | " Water | " " | " " " " " | |
| | " " | " Bornite | " " " " " | |
| 8 | " " | " " | " " " " " | |
| | " " | " " " | " " " " " | |
| | " " | " " " | " " " " " | |
| | " " | Pyrite, chalcocite | " " " " " | |
| | " " | " " | " " " " " | |
| 9 | " " | " " | " " " " " | |
| | " " | " " | " " " " " | |
| | " " | " " | " " " " " | |
| | " " | Arsenopyrite | " " " " " | Monzonite Metal Mostly Chalcopyrite |
| | " " | " Enargite | " " " " " | |
| 15 | " " | " " | " " " " " | |
| | " Hard | " " | " " " " " | |
| 16 | " " | " " | " " " " " | |
| 17 | " " | " " | " " " " " | |
| | Medium | Chalcopyrite | " " " " " | |
| | " " | " Pyrite | " " " " " | |
| | " " | " " | " " " " " | |
| 18 | " " | " " | " " " " " | |
| | " " | " " | " " " " " | |
| | " " | " " | " " " " " | |
| 19 | " " | " " | " " " " " | |
| | " " | " " | " " " " " | |
| | " " | " " | " " " " " | |
| 20 | " " | " " | " " " " " | |

Fig. 3. Churn Drill Data Form of 1924

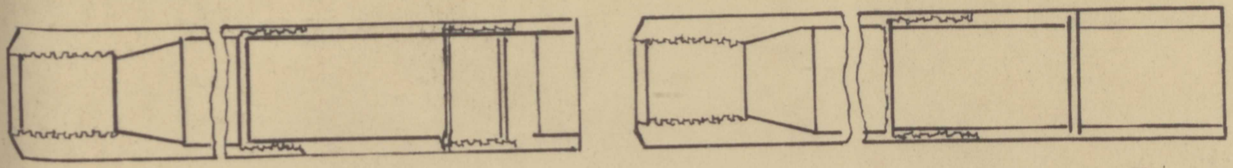


Fig. 5. Single Tube Core Barrel

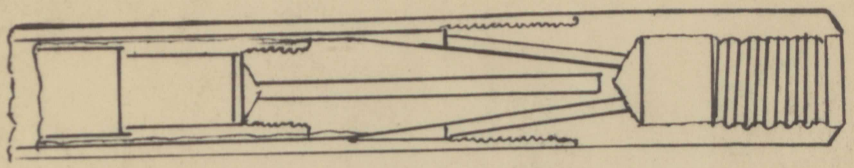


Fig. 6. Double Tube Core Barrel

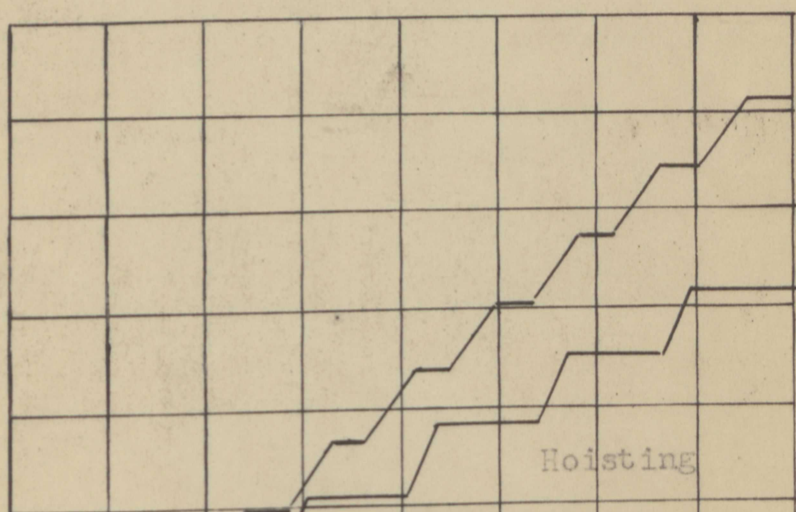



Fig. 7. Time Footage Graph

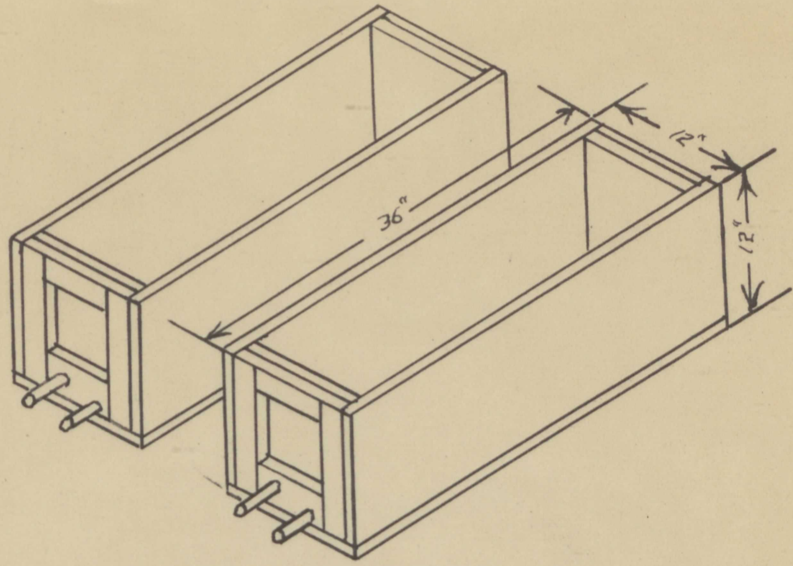
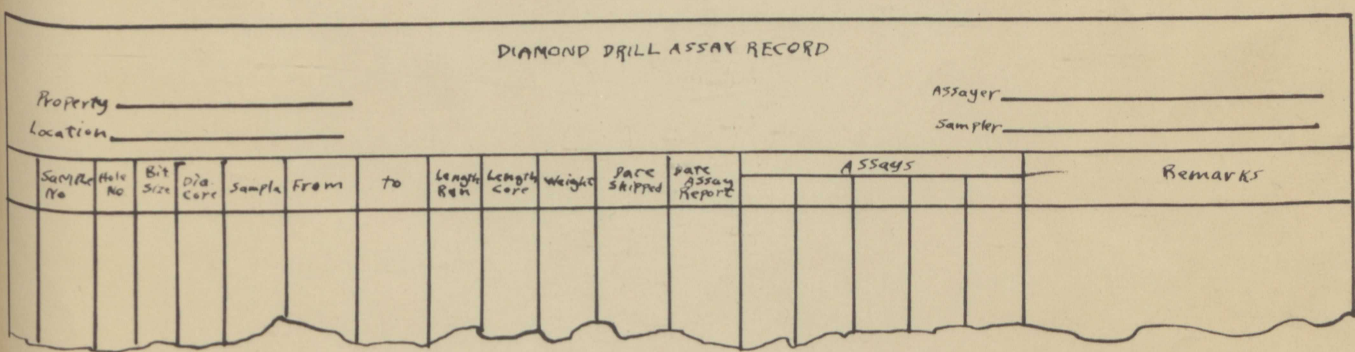



Fig.8. Sludge Box


DIAMOND DRILL ASSAY RECORD

Property ____________ Assayer ____________

Location ____________ Sampler ____________

| | Sample No | Hole No | Bit Size | Dia Core | Sample | From | to | Length Run | Length Core | Weight | Date Shipped | Date Assay Report | Assays | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | |

Fig.9. Standard Diamond Drill Assay Record

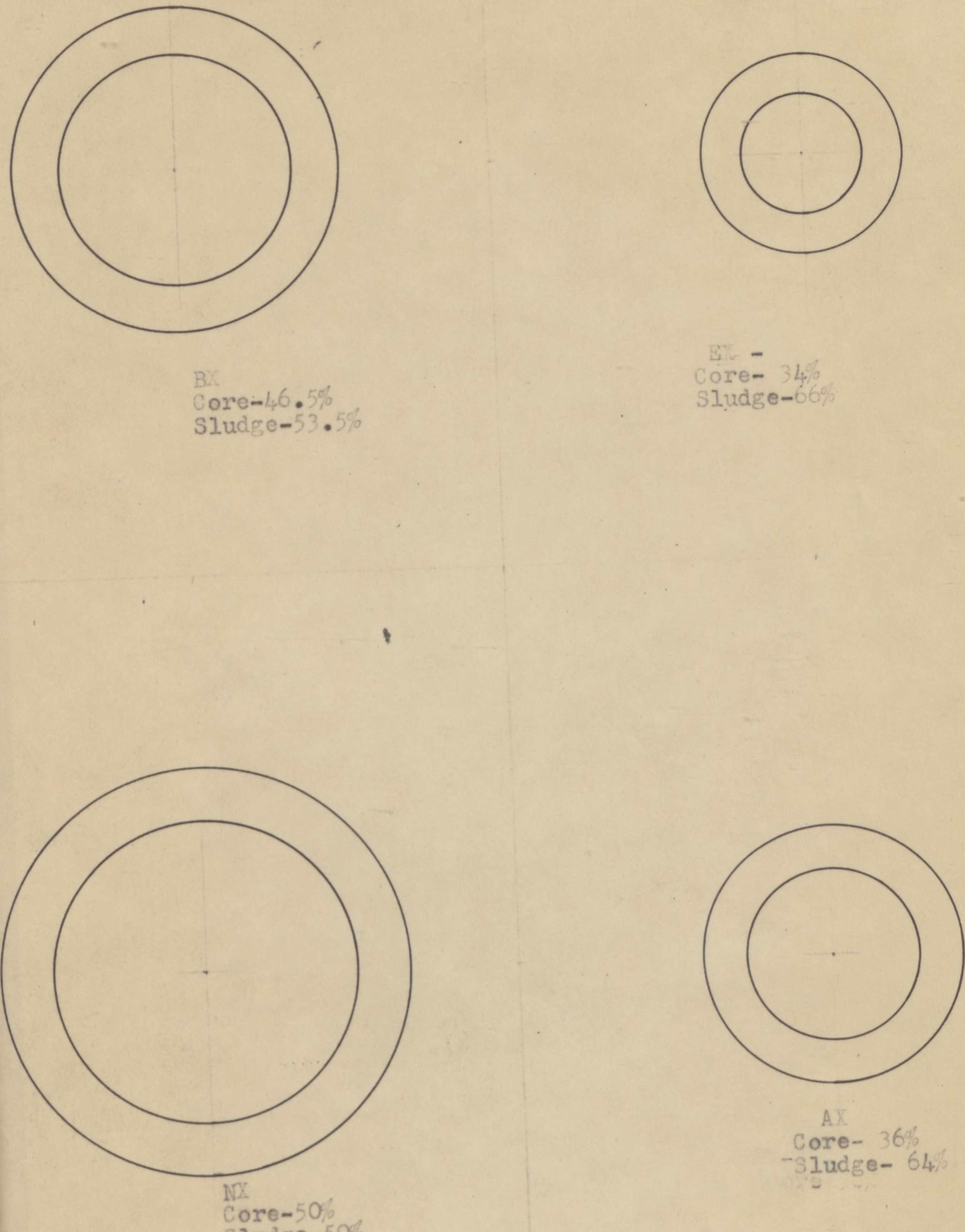
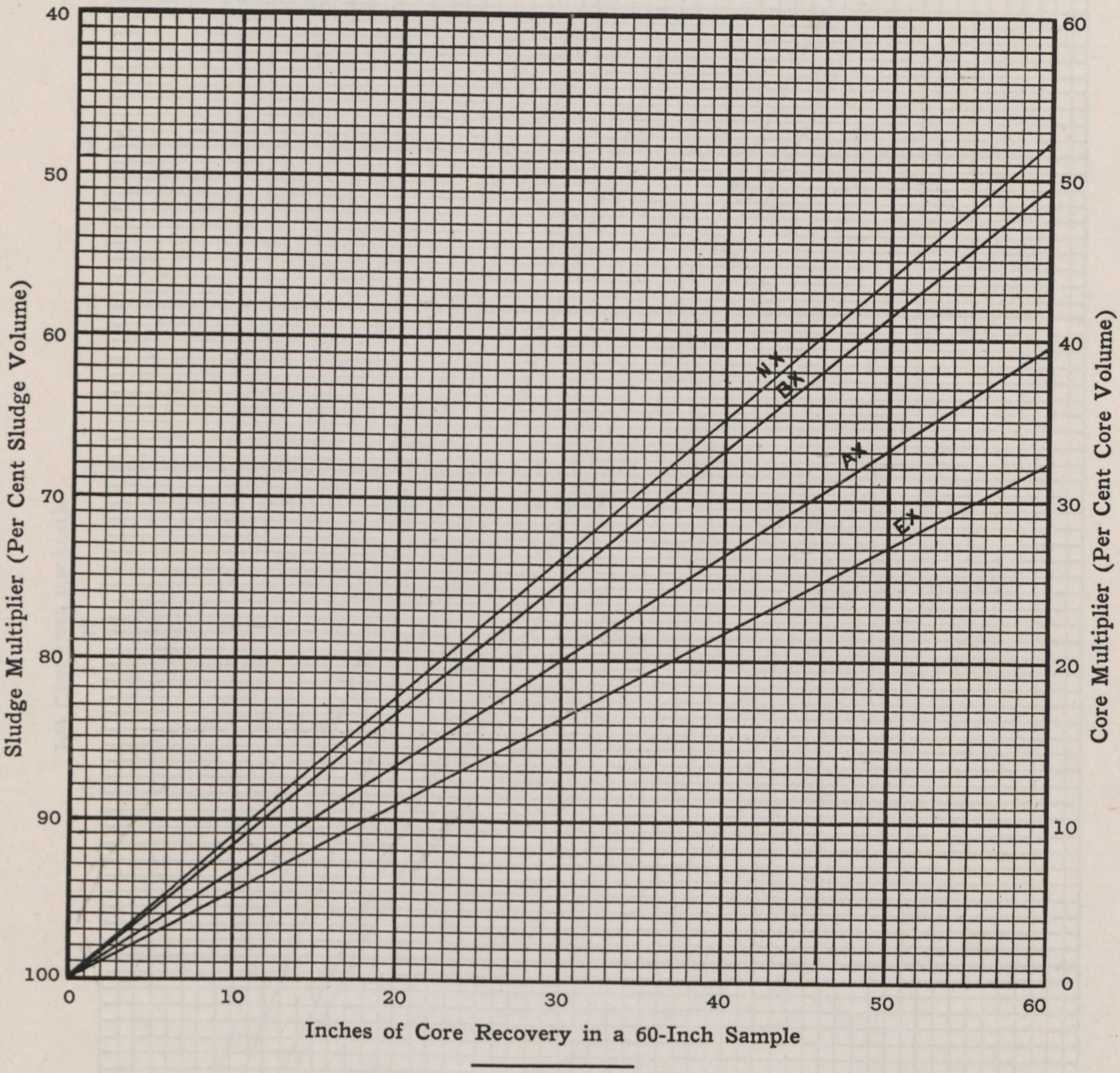



Fig.10. Sludge Core Ratios

# CHART FOR COMBINING CORE AND SLUDGE ANALYSES

**This simple chart gives you multipliers for combining by volume the analyses of separately analyzed diamond drill core and sludge samples.**



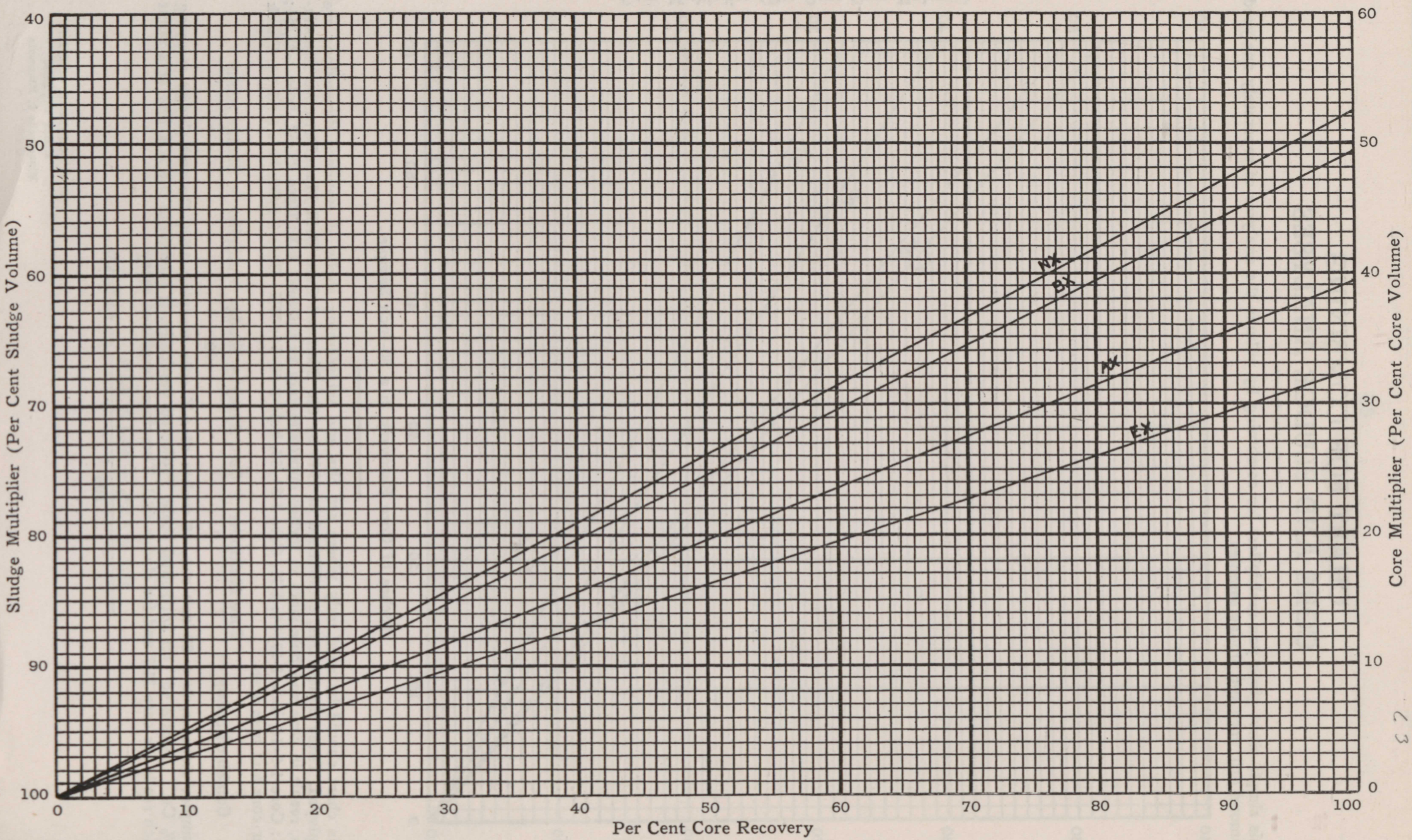

**This chart should be used only where set bits and set reaming shells of standard dimensions are employed. These dimensions, established in 1943 by the Diamond Core Drill Manufacturers Association, result in core and hole sizes in inches approximately as follows: EX: Core 27/32, hole 1-31/64; AX: Core 1-3/16, hole 1-57/64; BX: Core 1-21/32, hole 2-23/64; NX: Core 2-5/32, hole 2-63/64. Check your core and hole sizes.**

$$\text{Combined Assay} = \frac{\text{Core Multiplier} \times \text{Core Assay} + \text{Sludge Multiplier} \times \text{Sludge Assay}}{100}$$

**Example: Assume, in a 60-inch run, 48 inches of AX core assaying 4.6% Cu and sludge assaying 5.1% Cu. Locate 48″ on horizontal scale. Projected vertically, it intercepts the AX line at a point which reads for core 31.7 and for sludge 68.3. Therefore, combined assay**

$$= \frac{31.7 \times 4.6\% + 68.3 \times 5.1\%}{100} = 4.9\%\ \text{Cu.}$$

**E. J. LONGYEAR COMPANY**
**Mining Engineers**
**Minneapolis 2, Minnesota**


Sludge Multiplier (Per Cent Sludge Volume)
40
50
60
70
80
90
100
Core Multiplier (Per Cent Core Volume)
60
50
40
30
20
10
0
Per Cent Core Recovery
0
10
20
30
40
50
60
70
80
90
100
NX
BX
AX
EX
c3

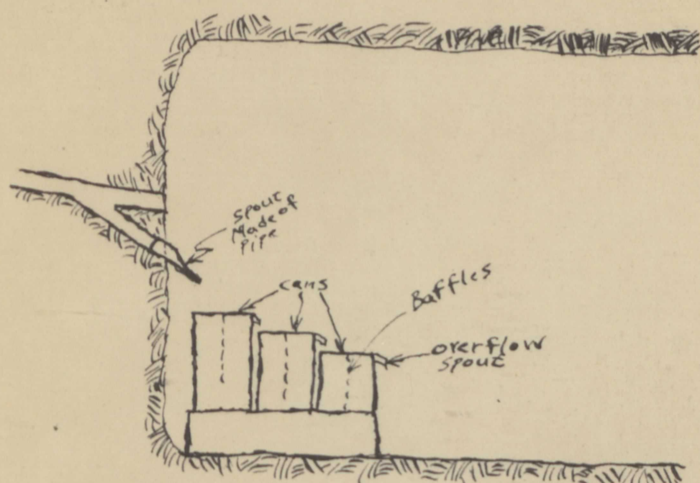



Fig.12. Method of Catching Deep Hole Sludge in Hammer Drilling.

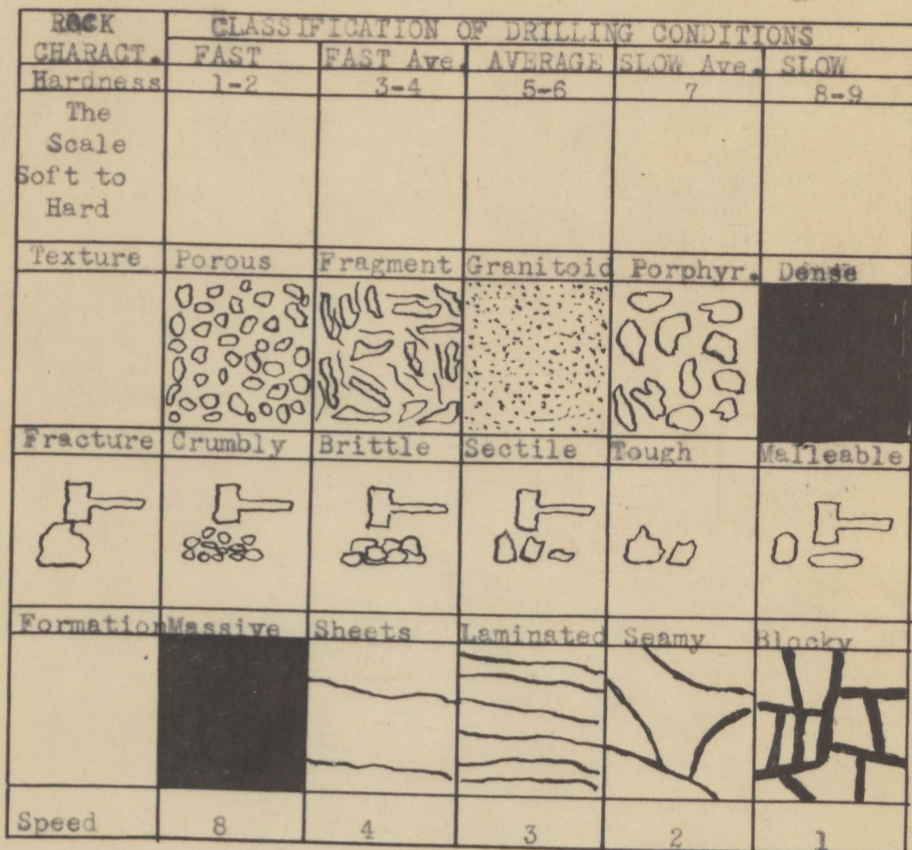



Figure 13. Rock Drilling Characteristics

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